

## **Design of a Dedicated Medical Synchrotron X-ray Facility Primarily for Microbeam Radiation Therapy (MRT)**

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**Introduction:** Microbeam radiation therapy (MRT) is an experimental technique that uses arrays of parallel, thin ( $<100\text{ }\mu\text{m}$ -wide) microplanar beams of synchrotron-generated x rays [1]. Preclinical MRT research, which originated at the NSLS in the early 1990s [1] and is now pursued at the NSLS and at the European Synchrotron Radiation Facility (ESRF), Grenoble, France [2, 3], has disclosed two radio therapeutically remarkable effects. First, single-exposure unidirectional MRT largely spares normal tissues, including the normal eye, brain, spinal cord, and skin of several mammals, using in-beam doses up to 20 times larger than those tolerated in broad beam radiotherapies [1-5]. Second, single-exposure unidirectional MRT ablates intracerebral gliosarcomas in rats [6-8] and subcutaneous mammary carcinomas in mice [9] at in-beam doses, which, although considered excessive in conventional radiotherapy, are nevertheless tolerated by contiguous normal tissues. The normal-tissue sparing of MRT may be partly mediated by vascular endothelial cells that survive between microbeams and enable rapid repair of the contiguous damaged endothelium [1]. The preferential damage of tumor by unidirectional MRT has been attributed, at least in part, to putative differences between mechanisms of post-irradiation repair of the vasculatures of normal and neoplastic tissues [7-10]. We now present the broad outline of a design for a dedicated medical synchrotron radiation facility to be used mainly for clinical MRT.

**Methods and Materials:** Using a median beam energy of 130 keV (obtained with copper filtration) as the energy of choice, our design sets as a goal a 10,000 Gy/s incident skin dose rate. For cost effectiveness we set the storage ring energy at 2.8 GeV, although the range of optimal energies (which is expected to be broad) extends to about 4 GeV. The ring's lattice could be that at the NSLS [11] with the same 16 bending magnets and six available straight sections in the 170 m circumference. The RF would be 500 MHz and the maximum current, 300 mA. The ring's emittance and other parameters, and the special design of the wigglers, would be tailored to the needs of clinical MRT. There could be a 7 tesla superconducting wiggler in every available straight section. The desired 10,000 Gy/s, which requires only 12 m source-subject distance, provides an 15 cm-wide treatment volume and would enable a 200 Gy incident dose to be delivered in 1/50 s, minimizing risks from patient movement. Only if clinical research using existing non-dedicated facilities achieves clinically gratifying results would a dedicated high-patient-throughput facility with six wigglers be justified. Because MRT is expected to be delivered in only one or, at most, a few sessions, a six-suite MRT facility should provide a sufficiently high patient throughput to serve any large metropolitan area for the foreseeable future. Such a facility's bending-magnet beamlines could be used for clinical radiography such as Diffraction Enhanced Imaging (DEI) [12]. The existing synchrotron facilities with ring- and wiggler-designs that could support clinical MRT research at close to optimal conditions are the APS and NSLS (USA), ESRF (France), and Spring 8 (Japan).

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